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(54) HIGH STRUCTURE BOLT EXCELLENT IN DELAYED FRACTURE RESISTANCE

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a high strength bolt excellent in delayed fracture resistance which has a tensile strength of over 1200 N/mm2.

SOLUTION: This bolt which is composed of a steel including C: 0.5-1.0% restrains the structure generation of one kind or more than one kind of pro- eutectoid ferrite, pro-eutectoid cementite, bentonite and martensite to make the area rate of pearlite structure with pearlite lamelar interval 200 nm or less to be 80% or above. Then, the high strength wire material which is made to have a tensile strength of over 1200 N/mm2 and excellent delayed fracture resistance by strong extension work is used. The material is cut to a fixed length and both end parts are threaded by thread rolling or cutting.

[Claim 1]It consists of steel containing C:0.5 to 1.0% (it is [a meaning of mass %, and the following] the same), Generation of one sort or two sorts or more of organizations of a proeutectoid ferrite, free cementite, bainite, and martensite is controlled, A perlite lamellar interval makes an area rate of pearlite texture which is 200 nm or less not less than 80%, And a high strength wire it was made to have intensity more than 1200-N[/mm] ^{2} and the outstanding delayed fracture-proof nature by strong wire drawing is used, A

high intensity bolt excellent in delayed fracture-proof nature ****ing and processing both ends by thread rolling or cutting after cutting this to predetermined length.

[Claim 2]Si: Less than 2.0% (0% is not included) and/or Co: The high intensity bolt according to claim 1 which uses a high strength wire containing 0.5% or less (0% is not included).

[Claim 3]Cr: The high intensity bolt according to claim 1 or 2 which uses a high strength wire containing 1.0% or less (0% is not included).

[Claim 4]Consist of steel containing C:0.5 to 1.0%, and A proeutectoid ferrite, free cementite, Generation of one sort or two sorts or more of organizations, bainite and martensite, is controlled, A perlite lamellar interval makes an area rate of pearlite texture which is 200 nm or less not less than 80%, And a high strength wire it was made to have intensity more than 1200-N[/mm] ^{2} and the outstanding delayed fracture-proof nature by strong wire drawing is used, A high intensity bolt which formed a bolt-head part in an end on the other hand, and was excellent before warm forging or in the back in an another side end by warm forging at thread rolling or delayed fracture-proof nature ****ed and processed after cutting this to predetermined length.

[Claim 5]Si: Less than 2.0% (0% is not included) and/or Co: The high intensity bolt according to claim 4 which uses a high strength wire containing 0.5% or less (0% is not included).

[Claim 6]Cr: The high intensity bolt according to claim 4 or 5 which uses a high strength wire containing 1.0% or less (0% is not included).

[0001]
[Field of the Invention]This invention relates to the high intensity bolt used as the object for cars, or various objects for industrial machines.
Though especially intensity (tensile strength) is more than 1200-N[/mm] ^{2}, it is related with the high intensity high intensity bolt excellent in delayed fracture-proof nature etc.

[0002]
[Description of the Prior Art]Inside carbon alloy steel (SCN435, SCN440, SCr440 grade) is used, and he is trying to secure required intensity by hardening and annealing as common steel for high intensity bolts. However, in the general high intensity bolt used as the object for cars, or various objects for industrial machines, when tensile strength becomes a field exceeding about 1200-N[/mm] ^{2}, there is a risk of delayed fracture occurring and there are restrictions on use.

[0003]Although delayed fracture has what happens under non-corrosive environment, and a thing which happens under corrosive environment, the factor of versatility [generation cause / the] is said to be entangled intricately.
It is difficult to specify the above-mentioned cause generally.
As a controlling factor which influences the above delayed fracture nature, Although the intervention of tempering temperature, an organization, material hardness, a grain size number, various alloy elements, etc. is accepted once, the actual condition is only that the effective means for preventing delayed fracture is not necessarily established, and various methods are proposed by trial and error.

[0004]In order to improve delayed fracture-proof nature, art, such as JP,60-114551,A, JP,2-267243,A, and JP,3-243745,A, is proposed, for example. As for such art, at least 1400 or more MPa of tensile strength are made by adjusting various kinds of main alloy elements aiming at the development of steel for high intensity bolts excellent in delayed fracture-proof nature. However, it did not necessarily say that the danger of delayed fracture generating was thoroughly canceled by such art, and those scopes have stopped at the very limited range.

[0005]
[Problem(s) to be Solved by the Invention]This invention is made paying attention to such a situation, and the purpose is to provide the high intensity bolt excellent in delayed fracture-proof nature, though tensile strength is more than 1200-N[/mm] ^{2}.

[0006]
[Means for Solving the Problem]With a high intensity bolt of this invention which could attain the above-mentioned purpose. It consists of steel containing C:0.5 to 1.0% (it is [a meaning of mass %, and the following] the same), Generation of one sort or two sorts or more of organizations of a proeutectoid ferrite, free cementite, bainite, and martensite is controlled, A perlite lamellar interval makes an area rate of pearlite texture which is 200 nm or less not less than 80%, And after using a high strength wire it was made to have intensity more than 1200-N[/mm] ^{2}, and the outstanding delayed fracture-proof nature and cutting this to predetermined length by strong wire drawing, it has a gist at a point of ****ing and processing both ends by thread rolling or cutting.

[0007]The purpose of describing this invention above consists of steel containing C:0.5 to 1.0%, and A proeutectoid ferrite, Generation of one sort or two sorts or more of organizations of free cementite, bainite, and martensite is controlled, A perlite lamellar interval makes an area rate of pearlite texture which is 200 nm or less not less than 80%, And a high strength wire it was made to have intensity more than 1200-N[/mm] ^{2} and the outstanding delayed fracture-proof nature by strong wire drawing is used, After cutting this to predetermined length, on the other hand, a bolt-head part is formed in an end by warm forging, and an another side end is attained in front of warm forging or in the back also by adopting thread rolling or composition of a high intensity bolt which is ****ed and processed.

[0008]It is effective in a high intensity bolt of this invention to also make less than (1) Si:2.0% (0% is not included) and/or less than Co:0.5% (0% is not included), and less than (2) Cr:1.0% (0% is not included) contain if needed.

[0009]
[Embodiment of the Invention]This invention persons examined the cause that the delayed fracture-proof nature of the conventional high-strength steel for bolts is inferior, from various angles. As a result, although delayed fracture-proof nature had been compensated with the conventional corrective strategy by annealing an organization and attaining evasion of a temper brittleness region, reduction of a grain-boundary-segregation element, and grain refining as martensite, by such a means, it became clear that there was a limit in raising the delayed fracture-proof nature of high-strength steel.

[0010]Then, the result of having repeated research wholeheartedly in order that this invention persons might raise delayed fracture-proof nature further, The organization was considered as the organization of the perlite subject with a certain restrictions, when processing it into the bolt using the high strength wire made into the intensity more than 1200-N[/mm] ^{2} by strong wire drawing, it found out that the high intensity bolt with which the outstanding delayed fracture-proof nature is demonstrated was obtained, and this invention was completed.

[0011]Like **** the high strength wire used as a raw material by this invention A proeutectoid ferrite, It is necessary to control generation of one sort or two sorts or more of organizations of free cementite, bainite, and martensite, and a perlite lamellar interval needs to make the area rate of the pearlite texture which is 200 nm or less not less than 80%. When a proeutectoid ferrite and free cementite generate mostly among the above-mentioned organizations, start a longitudinal crack at the time of wire drawing, wire drawing becomes impossible, and it becomes impossible to obtain the intensity more than 1200-N[/mm] ^{2} by strong wire drawing. Since an open circuit is caused at the time of wire drawing, it is necessary to lessen free cementite and martensite. Since the amount of work hardening of bainite decreases compared with perlite, and an intensity rise by strong wire drawing cannot be expected, it is necessary to lessen as much as possible.

[0012]On the other hand, the pearlite texture of the remainder carries out the trap of the hydrogen by the interface of cementite and a ferrite, and is effective in reducing the hydrogen accumulated on a grain boundary, and it is necessary to make [many / as possible] it. it is necessary to control one sort or two sorts or more of histogenesis of a proeutectoid ferrite, free cementite, bainite, and martensite as much as possible (namely, -- making it to less than 20%), and to make the area rate of pearlite texture into not less than 80% from such a thing That is, at least one sort of the organization of a proeutectoid ferrite, free cementite, bainite, martensite, etc. is lessened as much as possible, and as the area rate of the sum total will be less than 20%, it needs to make the area rate of pearlite texture not less than 80%. The area rate of pearlite texture is good to consider it as pearlite texture 100% often [considering it as not less than 90% preferably], and more preferably.

[0013]Pearlite texture requires that a perlite lamellar interval should be 200 nm or less. Effective in high-intensity-izing of steel materials, as above-mentioned, the minuteness making of a perlite lamellar interval makes the interface of cementite and a ferrite increase, and promotes a hydrogen trapping effect. In order to fully demonstrate such an effect, it is required for a perlite lamellar interval to be 200 nm or less. A desirable perlite lamellar interval is 150 nm or less, is 100 nm or less more preferably, and is 75 nm or less still more preferably.

[0014]In the wire rod used as a raw material by this invention, since it becomes difficult for dimensional accuracy required still in [forge] the state with rolling not to be acquired, and to obtain the intensity more than 1200-N[/mm] ^{2}, strong wire drawing is needed. The cementite in a part of perlite is minutely distributed by strong wire drawing, and hydrogen trap capacity is raised by it, and when an organization stands in a line in accordance with the direction of wire drawing, it becomes resistance of progress of a crack (the direction of crack propagation is vertical to the direction of wire drawing).

[0015]Although the high intensity bolt of this invention assumes the medium carbon steel which contains C 0.5 to 1.0%, the reason for range limitation of C content is as follows.

[0016]C:0.5 to 1.0%C is an element required because of intensity reservation of steel, and economical, and intensity increases it as C content is made to increase. In order to secure target strength, it is necessary to make C contain 0.5% or more. However, if C content exceeds 1.0%, the precipitation amount of free cementite increases, and the fall of ****** will appear notably and will degrade wire drawing workability. The desirable minimum of C content is 0.65%, and is 0.7% more preferably. The desirable maximum of C content is 0.95%, and is good to consider it as 0.9% more preferably.

[0017]Although the various elements (Si, Co, Mn, Cu, nickel, Cr, Mo, Ti, Nb, V, W, aluminum, B, etc.) usually added may be contained of course in the high intensity bolt of this invention, It is effective to make especially Si and Co of the specified quantity contain, when controlling the deposit of free cementite, and Cr is effective in carrying out minuteness making of the lamellar interval of perlite, and improving the intensity and wire drawing workability of a wire rod. The reason for limitation of each element added as occasion demands is as follows.

[0018]Si: Demonstrate the effect of Si raising the hardenability of a steel wire 2.0% or less (0% is not included), and suppressing the deposit of free cementite. The operation as a deoxidizer is expected, moreover, it dissolves to a ferrite, and a remarkable solid-solution-strengthening operation is also demonstrated. These effects increase as the content increases, but since the ductility of the steel wire after wire drawing will be reduced if a Si content becomes superfluous, they make 2.0% a maximum. The maximum with a preferred Si content is 1.0%, and is 0.5% more preferably.

[0019]Co: Co is effective 0.5% or less (0% is not included) especially as an addition ingredient in the high intensity bolt of this invention which there is an effect which controls the deposit of free cementite like Si, and aims at reduction of free cementite. The

more content increased, the more such an effect increased, but since the effect was saturated and became uneconomical even if it made it contain exceeding 0.5%, the maximum was made into 0.5%. It is good for the desirable range of Co content to be 0.05 to 0.3%, and to carry out the minimum and to make the maximum 0.2% 0.1% still more preferably.

[0020]Cr: There is an operation which Cr carries out minuteness making of the lamellar interval of perlite 1.0% or less (0% is not included), and improves the intensity and wire drawing workability of a wire rod. However, if a Cr content becomes superfluous, in order for transformation finish temperature to become long too much similarly and to cause degradation of the large-sized fault of equipment, and productivity, let 1.0% be a maximum. The minimum with a preferred Cr content is 0.05%, and is good to consider it as 0.1% more preferably. The maximum with a preferred Cr content is 0.5%, and is good to consider it as 0.3% more preferably.

[0021]Mn: 0.2 to 1.0%Mn demonstrates the effect as a deoxidizer, and the effect which raises the hardenability of a steel wire and improves the homogeneity of the organization of a steel wire. In order to demonstrate these effects, it is necessary to make it contain 0.2% or more. However, since super cooling organizations, such as martensite and bainite, will generate to the segregation part of Mn and wire drawing workability will be degraded if a Mn content becomes superfluous, let 1.0% be a maximum. The minimum with a preferred Mn content is 0.40%, and is good to consider it as 0.45% more preferably. The maximum with a preferred Mn content is 0.70%, and is good to consider it as 0.55% more preferably.

[0022]Cu: Cu is an element contributed to high intensity-ization of a steel wire by precipitation-hardening operation 0.5% or less (0% is not included). However, since it will become the cause of causing grain boundary embrittlement and degrading delayed fracture-proof nature if it adds superfluously, let 0.5% be a maximum. The minimum with preferred Cu content is 0.05%, and is good to consider it as 0.1% more preferably. The maximum with preferred Cu content is 0.3%, and is good to consider it as 0.2% more preferably.

[0023]nickel: Although nickel is seldom contributed to an intensity rise of a steel wire 1.0% or less (0% is not included), it has an effect which improves the toughness of wire-drawing material. However, if a Ni content becomes superfluous, in order for transformation finish temperature to become long too much like Cr and to cause degradation of the large-sized fault of equipment, and productivity, let 1.0% be a maximum. The minimum with a preferred Ni content is 0.05%, and is good to consider it as 0.1% more preferably. The maximum with a preferred Ni content is 0.5%, and is good to consider it as 0.3% more preferably.

[0024]One or more sorts chosen from the group which consists of Mo, Ti, Nb, V, and W: The element of these forms detailed charcoal and nitride 0.01 to 0.5% in total, and contribute to improvement in delayed fracture-proof nature. These carbide and nitrides are effective also in the minuteness making of a crystal grain. in order to demonstrate

such an effect, it is necessary to make it contain 0.01% or more in total but, and since delayed fracture-proof nature and toughness will be checked if it is made to contain superfluously, it is necessary to make it to 0.5% or less in total The minimum with such preferred elemental content is 0.02% in total, and is good to consider it as 0.03% more preferably. A desirable maximum is 0.3% in total, and is good to consider it as 0.1% more preferably.

[0025]aluminum: 0.01 to 0.05%aluminum catches N in steel, forms AlN, and contributes to improvement in delayed fracture-proof nature by carrying out minuteness making of the crystal grain. For that purpose, although it is necessary to make it contain 0.01% or more, since nitride system inclusion and oxide stock inclusion will generate and drawability will fall if it exceeds 0.05%, it is necessary to make it to 0.05% or less. The minimum with preferred Al content is 0.025%, and a desirable maximum is 0.035%.

[0026]In order to demonstrate the effect, it is necessary to make B:0.0005 to 0.003%B contain 0.0005% or more, although added for the improvement in hardenability of steel. However, if superfluously contained exceeding 0.003%, toughness will be checked on the contrary. The desirable minimum of B content is 0.0010%, and a desirable maximum is 0.0025%.

[0027]When N:0.015%or less (0% is not included) N forms nitrides, such as AlN and TiN, minuteness making ****** of a crystal grain has good influence on improvement in delayed fracture-proof nature. However, since it not only may have an adverse effect on drawability, but a nitride increases too much and the dissolution N may promote the prescription in wire drawing when contained superfluously, it is necessary to make it to 0.015% or less. The desirable maximum of N content is 0.007%, and is good to make it to 0.005% or less more preferably.

[0028]In the high strength wire of this invention, although the above-mentioned ingredients consist of iron fundamentally (remainder), what may contain a minor constituent and contains ** and such an ingredient besides these is contained in the technical scope of this invention. Considering the viewpoint of making the characteristic still better, about P, S, and O, it is good to control as follows. Although an impurity will be contained in the high strength wire of this invention unescapable, they are permitted in the limit which does not spoil the effect of this invention.

[0029]P:0.03%or less (0% is included) P is an element which starts grain boundary segregation and degrades delayed fracture-proof nature. Then, by making P content into 0.03% or less, improvement in delayed fracture-proof nature can be aimed at. P content is good to make it to 0.005% or less preferably [decreasing to 0.015% or less], and more preferably.

[0030]S:0.03%or less (0% is included) S forms MnS in steel, and when load of the stress is carried out, MnS serves as a stress concentration part. Therefore, it is good for it to be necessary for the improvement of delayed fracture-proof nature to decrease S content as much as possible, and to make it to 0.03% or less. S content is good to make it to 0.005%

or less preferably [decreasing to 0.01% or less], and more preferably.

[0031]At ordinary temperature, O:0.005%or less (0% is included) O hardly dissolves to steel, but exists as hard oxide stock inclusion, and becomes a cause which causes a KAPPI open circuit at the time of wire drawing. Therefore, O content should be made few as much as possible, and it is necessary to stop it to at least 0.005% or less. As for O content, decreasing to 0.003% or less is preferred, and it is good to decrease to 0.002% or less more preferably.

[0032]Although the high strength wire used as a raw material by this invention can adjust the organization with various methods, it explains the typical method. As one of methods, the steel materials which have the above chemical entities first are used, After performing hot-rolling or hot forging so that rolling or forge finish temperature of steel materials may be not less than 800 **, as following the (1) type is satisfied, continuous cooling of the average cooling rate V (**/second) is carried out to 400 **, and the method of cooling radiationally succeedingly is mentioned.
$166x(\text{wire size})^{-1.4} <= V <= 288x(\text{wire size})^{-1.4}$ -- (1)

[0033]By this process, pearlite texture more homogeneous than the usual rolled stock is obtained, and the intensity rise before wire drawing can be aimed at. Since austenitizing will become insufficient and homogeneous pearlite texture will no longer be obtained if rolling or forge finish temperature is too low, the above-mentioned finish temperature needs to be not less than 800 **. The range with this preferred temperature is about 850-950 **, and is about 850-900 ** still more preferably.

[0034]If the above-mentioned average cooling rate V becomes smaller than $166x(\text{wire size})^{-1.4}$, it will become easy to generate homogeneous pearlite texture not only no longer being obtained but a proeutectoid ferrite, and free cementite. If the average cooling rate V becomes larger than $288x(\text{wire size})^{-1.4}$, it will become easy to generate bainite and martensite.

[0035]Also by quenching the high strength wire used by this invention to the temperature of 520-650 ** using the steel materials which have the above chemical composition after heating these steel materials at not less than 800 **, and carrying out homoiothermal maintenance (patenting treatment) at that temperature, Pearlite texture more homogeneous than the usual rolled stock is obtained, and the intensity rise before wire drawing can be aimed at.

[0036]In this method, it may be necessary to be not less than 800 ** about the stipulated range of steel-materials cooking temperature for the same reason as the above-mentioned rolling or forge finish temperature. The range with this preferred cooking temperature is the same as that of the above. As for patenting treatment, it is desirable to quench the wire rod which used a salt bath, lead, the fluid bed, etc. and was heated with the quickest possible cooling rate. In order to obtain homogeneous pearlite texture, it is required at 520-650 ** to carry out isothermal transformation. The temperature requirement where this isothermal transformation temperature is preferred is 550-600 **, and the most

desirable homoiothermal retention temperature is the temperature near the perlite nose of a TTT diagram.

[0037]On the other hand, rolling of steel materials or the temperature after the end of a forge so that it may become not less than 800 ** Hot-rolling or after carrying out hot forging, Also by cooling to the temperature of 520-750 ** with the average cooling rate at not less than 5 **/second, holding 200 seconds or more and cooling radiationally succeedingly with the average cooling rate at 1.0 **/second or less, from the temperature, pearlite texture more homogeneous than the usual rolled stock is obtained, and the intensity rise before wire drawing can be aimed at. The operation in each process when adopting such a method is as follows.

[0038]About the stipulated range of the temperature after rolling or the end of a forge, it was first determined as not less than 800 ** for the same reason as the above-mentioned steel-materials cooking temperature. The range with this preferred temperature is the same as that of the above. When the cooling rate after hot-rolling or hot forging is too slow, it is preferred to cause a ferrite transformation during cooling and to cool with the quickest possible cooling rate. Then, the cooling rate at this time was specified in not less than 5 **/second. The range with this preferred cooling rate is not less than 10 **/second, and is not less than 30 **/second more preferably. Although it is necessary to cool to 520-750 ** by this cooling, if this cooling finishing temperature exceeds less than 520 ** or 750 **, subsequent annealing will become easy to generate the organization of those other than perlite.

[0039]After cooling above, it is necessary to hold 200 seconds or more from a viewpoint of obtaining homogeneous pearlite texture, cooling by being in the average cooling rate at 1.0 **/second or less from the temperature (temperature of 520-750 **: annealing starting temperature) (annealing). If the average cooling rate at this time will become quicker 1.0 ** /than a second or retention time will be less than 200 seconds, it will be cooled radiationally before metamorphosing into pearlite texture, and will become easy to generate bainite and martensite. The range with this preferred cooling rate is 0.5 **/second or less, and is good to make it more desirable in 0.2 **/[a second and] or less. The desirable range of the above-mentioned retention time is 300 seconds or more, and is good to consider it as 600 seconds or more more preferably. It is most preferred to hold for a long time to the temperature near the perlite nose of a TTT diagram.

[0040]After using the high strength wire produced by performing it above and cutting to predetermined length, (1) **** both ends by thread rolling or cutting, and process them, or (a stud bolt is used). Or a bolt-head part is formed in the end part by (2) warm forging, and the bolt which demonstrates the delayed fracture-proof characteristic and intensity outstanding by ****ing the other end by thread rolling or cutting, and processing it before warm forging or on the back etc. is obtained. Since the intensity of a wire rod is high, it is from the reason for being hard to fabricate to predetermined bolt shape in the usual cold forging to adopt a warm forging method, when forming a bolt-head part in the method of the above (2).

[0041]Although an example explains this invention still in detail below, each thing which the following example is marked on the meaning of front and a postscript instead of the thing of the character which limits this invention, and is done for a design variation is included in the technical scope of this invention.

[0042]
[Example]After hot-rolling using the sample offering steel which has the chemical composition shown in the example 1 following table 1 so that rolling complete temperature may be about 930 ** to wire-size:11mmphi and 14mmphi, air blast cooling of the average cooling rate was carried out as a range of 4.2-12.1 ** (the following table 2)/second. Then, a wire size: Wire drawing was carried out to 7.06 mm (wire drawing rate: 59%, 75%).

[0043]

[Table 1]

供試鋼	化学成分(質量%)								
	C	Si	Mn	P	S	Al	N	O	その他
B	0.60	0.83	0.49	0.008	0.003	0.030	0.004	0.0007	—
C	0.82	0.89	0.50	0.005	0.002	0.031	0.004	0.0007	—
D	0.97	0.48	0.49	0.005	0.004	0.029	0.005	0.0008	—
E	1.30	0.90	0.53	0.005	0.003	0.031	0.005	0.0007	—
F	0.87	1.31	0.49	0.006	0.003	0.030	0.006	0.0007	—
G	0.90	2.23	0.50	0.006	0.003	0.033	0.005	0.0006	—
H	0.88	0.83	0.10	0.005	0.003	0.031	0.006	0.0055	—
I	0.87	0.85	1.22	0.006	0.002	0.030	0.006	0.0005	—
J	0.93	0.75	0.72	0.006	0.004	0.032	0.004	0.0008	Co:0.41
K	0.85	0.97	0.52	0.006	0.002	0.030	0.005	0.0006	Cr:0.32
L	0.86	0.96	0.53	0.006	0.002	0.030	0.005	0.0006	Cr:1.22
M	0.34	0.19	0.70	0.006	0.004	0.033	0.003	0.0009	Cr:0.95,Mo:0.18

[0044]The stud bolt of M8xP1.25 shown in drawing 1 was produced using the obtained various wire rods, and the delayed fracture examination was done. After immersing a bolt into acid (15%HClx 30 minutes), it rinsed and dried, stress load (load stress is 90% of tensile strength) of the delayed fracture examination was carried out in the atmosphere, and the existence of the fracture 100 hours after estimated it. The classification of a proeutectoid ferrite, free cementite, bainite, martensite, or pearlite texture was performed by the following method, and the area rate of each organization was searched for. The lamellar interval of perlite was measured by the following method. The delayed fracture examination was done also about what performed hardening and annealing and was made into tempering martensitic structure 100% about some things for comparison at this time (No.13 of the after-mentioned table 2).

[0045](Classifying method of each organization) The cross section of the wire rod was embedded, and after polish, after being immersed in 5% of picric-acid-alcohol liquid for 15 to 30 seconds and making it corrode, texture observation of the D/4 (D is a diameter) part was carried out under the scanning electronic thing microscope (SEM). After

carrying out 5-10 view photography by 1000 to 3000 times and becoming final and conclusive a pearlite texture portion, the area rate of each organization was searched for with the image analyzing device. About pearlite texture, and the bainite texture and proeutectoid ferrite organization which distinction cannot attach easily, the organization as shows drawing 2 (microphotograph for cost of blueprint) was made into the bainite texture, and the organization as shows drawing 3 (microphotograph for cost of blueprint) was judged to be a proeutectoid ferrite organization. As a tendency of these organizations, a proeutectoid ferrite and free cementite deposited needlelike along the old austenite grain boundary, and martensite deposited massive.

[0046](Measuring method of a perlite lamellar interval) The cross section of the wire rod was embedded, and after polish, after being immersed in 5% of picric-acid-alcohol liquid for 15 to 30 seconds and making it corrode, texture observation of the D/4 (D is a diameter) part was carried out under the scanning electronic thing microscope (SEM). Ten views of portions of the lamellar interval considered to be the narrowest were photoed by 5000 to 100000 times in the pearlite texture near D/4 copy, and the lamellar interval was measured in quest of the length of the line which crosses each lamellar one vertically. And the average value of ten views was specified as the perlite average lamellar interval.

[0047]It is shown in the following table 2 in the average cooling rate V, and a delayed fracture test result is shown for the organization of each wire rod in the following table 3 in a drawing condition and a mechanical property, respectively. The range with a proper average cooling rate [range with which it is satisfied of the aforementioned (1) formula] is 4.12<=V<=7.16 (**/second), when a wire size is 14 mm, and when a wire size is 11 mm, it is 5.78<=V<=10.03 (**/second).

[0048]

[Table 2]

試験 No.	供試鋼	初析フェライト面積率(%)	初析セメンタイト面積率(%)	ベイナイト面積率(%)	マルテンサイト面積率(%)	パーライト分率面積率(%)	パーライトラメラー間隔(nm.)	平均冷却速度V(℃／秒)	備考
1	C	27	0	0	0	73	152	4. 2	比較例
2	C	0	0	15	12	77	82	12. 1	比較例
3	B	18	0	0	0	82	118	6. 2	実施例
4	C	9	0	0	0	91	92	8. 7	実施例
5	D	31	11	0	0	86	78	8. 5	実施例
6	E	0	35	0	0	65	67	8. 6	比較例
7	F	6	0	0	0	94	99	8. 7	実施例
8	G	4	5	0	0	91	106	8. 5	参考例
9	H	10	0	0	0	90	72	9. 2	参考例
10	I	0	0	11	25	64	103	8. 5	比較例
11	J	3	9	0	0	88	65	8. 3	実施例
12	K	0	0	0	0	100	82	8. 7	実施例
13	L	0	0	9	23	68	73	8. 6	比較例
14	M	880℃×30分→OQ, 460℃×90分→WC(100%焼戻しマルテンサイト)						－	比較例

[0049]

[Table 3]

試験 No.	初期線径 (mm)	初期強度 (N/mm^2)	最終線径 (mm)	最終強度 (N/mm^2)	伸線率 (%)	伸線性	遅れ破壊性	備考
1	11.0	954	7.06	1311	59	良好	×	比較例
2	11.0	1221	7.06	1578	59	良好	×	比較例
3	14.0	814	7.06	1217	75	良好	○	実施例
4	11.0	1139	7.06	1496	59	良好	○	実施例
5	11.0	1213	7.06	1634	59	良好	○	実施例
6	11.0	1714	7.06	断線で伸線できず		断線	—	比較例
7	11.0	1298	7.06	1677	59	良好	○	実施例
8	11.0	1562	7.06	断線で伸線できず		断線	—	参考例
9	11.0	1097	7.06	断線で伸線できず		断線	—	参考例
10	11.0	1365	7.06	断線で伸線できず		断線	—	比較例
11	11.0	1288	7.06	1693	59	良好	○	実施例
12	11.0	1204	7.06	1573	59	良好	○	実施例
13	11.0	1221	7.06	断線で伸線できず		断線	○	実施例
14	11.0	—	7.06	1318	—	—	×	比較例

[0050]It quenched, after hot-rolling using the sample offering steel C shown in the example 2 aforementioned table 1 so that rolling complete temperature may be about 930 ** to wire-size:11mmphi, and patenting treatment (cooking temperature: 750-935 ** and isothermal transformation:495-670 **x 4 minutes) was carried out on the conditions shown in the following table 4. Then, a wire size: Wire drawing was carried out to 7.06 mm (wire drawing rate: 59%).

[0051]

[Table 4]

試験 No.	パテンティング時の加熱温度(℃)	恒温保持温度 (℃)	初析フェライト面積率(%)	初析セメンタイト面積率(%)	ベイナイト面積率(%)	マルテンサイト面積率(%)	パーライト面積率(%)	パーライトラメラー間隔(nm)	備考
15	935	560	2	0	0	0	98	78	実施例
16	750	550	41	5	9	0	59	72	比較例
17	930	670	25	0	0	0	75	223	比較例
18	930	495	0	0	30	3	67	62	比較例

[0052]The stud bolt of M8xP1.25 shown in said drawing 1 was produced using the obtained various wire rods, and the delayed fracture examination was done like Example 1. The organization of each wire rod is written together to said table 4, and a delayed fracture test result is shown in the following table 5 with a drawing condition and a mechanical property, respectively.

[0053]

[Table 5]

試験 No.	初期線径 (mm)	初期強度 (N/mm^2)	最終線径 (mm)	最終強度 (N/mm^2)	伸線率 (%)	伸線性	耐遅れ破壊性	備考
15	11.0	1227	7.06	1594	59	良好	○	実施例
16	11.0	1137	7.06	1494	59	良好	×	比較例
17	11.0	1188	7.06	1545	59	良好	×	比較例
18	11.0	1284	7.06	断線で伸線できず		断線	−	比較例

[0054]It hot-rolled to wire-size:11mmphi with the rolled bar affair shown in the following table 6 using the sample offering steel C shown in the example 3 aforementioned table 1. Then, a wire size: Wire drawing was carried out to 7.06 mm (wire drawing rate: 59%).

[0055]

[Table 6]

試験 No.	圧延終了温度 (℃)	圧延後冷却速度 (℃／秒)	徐冷開始温度 (℃)	徐冷の冷却速度 (℃／秒)	保持時間 (秒)	放冷開始温度 (℃)	備考
19	930	30	570	0.2	250	520	実施例
20	930	25	680	0.8	250	480	実施例
21	930	30	560	0.1	800	485	実施例
22	750	25	570	0.2	250	520	比較例
23	935	3	570	0.2	250	520	比較例
24	930	15	800	0.2	250	750	比較例
25	935	35	500	0.2	250	455	比較例
26	930	25	630	0.1	250	330	比較例
27	925	25	570	0.2	150	540	比較例

[0056]The stud bolt of M8xP1.25 shown in said drawing 1 was produced using the obtained various wire rods, and the delayed fracture examination was done like Example 1. A delayed fracture test result is shown for the organization of each wire rod in the following table 7 with a drawing condition and a mechanical property in the following table 8, respectively.

[0057]

[Table 7]

試験 No.	初析フェライト面積率(%)	初析セメンタイト面積率(%)	ベイナイト面積率(%)	マルテンサイト面積率(%)	パーライト分率面積率(%)	パーライトラメラー間隔(nm)	備考
19	4	0	0	0	96	82	実施例
20	8	0	0	0	92	105	実施例
21	5	0	0	0	95	71	実施例
22	42	0	10	0	58	80	比較例
23	44	0	0	0	56	82	比較例
24	29	0	0	0	71	235	比較例
25	0	0	32	10	58	68	比較例
26	0	0	26	15	59	203	比較例
27	0	0	10	39	51	81	比較例

[0058]

[Table 8]

試験 No.	初期線径 (mm)	初期強度 (N/mm^2)	最終線径 (mm)	最終強度 (N/mm^2)	伸線率 (%)	伸線性	遅れ破壊性	備考
19	11.0	1245	7.06	1602	59	良好	○	実施例
20	11.0	1249	7.06	1605	59	良好	○	実施例
21	11.0	1231	7.06	1588	59	良好	○	実施例
22	11.0	1132	7.06	1489	59	良好	×	比較例
23	11.0	1164	7.06	1520	59	良好	×	比較例
24	11.0	1188	7.06	断線で伸線できず		断線	—	比較例
25	11.0	1283	7.06	断線で伸線できず		断線	—	比較例
26	11.0	1312	7.06	断線で伸線できず		断線	—	比較例
27	11.0	1360	7.06	断線で伸線できず		断線	—	比較例

[0059]It turns out that the bolt with which it is satisfied of the requirements specified by this invention has the outstanding delayed fracture-proof nature even if tensile strength is more than 1200-N[/mm] ^{2} so that clearly from these results.

[0060]
[Effect of the Invention]This invention was constituted as mentioned above, and though tensile strength was more than 1200-N[/mm] ^{2}, the high intensity bolt excellent in delayed fracture-proof nature has been realized.